

## TABLE OF CONTENTS

|   |     |
|---|-----|
| Acknowledgements.....                       | i   |
| Executive Summary .....                     | iii |
| Table of Contents .....                     | v   |
| Appendices .....                            | vii |
| List of Tables .....                        | ix  |
| List of Figures .....                       | xi  |
| <br>  |     |
| Chapter 1: Introduction .....               | 1   |
| Background .....                            | 1   |
| Objectives.....                             | 2   |
| Data Sources.....                           | 6   |
| <br>  |     |
| Chapter 2: Geomorphology .....              | 7   |
| Climate.....                                | 7   |
| Topography and Surface Water Features ..... | 7   |
| <br>  |     |
| Chapter 3: Hydrogeologic System .....       | 13  |
| Groundwater Flow .....                      | 13  |
| Hydrostratigraphy and Hydrogeology .....    | 13  |
| Surficial Aquifer System .....              | 25  |
| Intermediate Confining Unit.....            | 27  |
| Floridan Aquifer System .....               | 31  |
| Upper Floridan Aquifer.....                 | 31  |
| Middle Confining Unit 1 .....               | 35  |
| Middle Floridan Aquifer.....                | 38  |
| Middle Confining Unit 2 .....               | 42  |
| Lower Floridan Aquifer .....                | 45  |
| Recharge and Discharge .....                | 47  |
| Watershed / Drainage Basins (dbasins) ..... | 47  |
| Potentiometric Levels.....                  | 50  |
| Historic and Projected Water Use .....      | 54  |
| Water Quality .....                         | 55  |

|  |            |
|--|------------|
| Surficial Aquifer System.....                          | 57         |
| Floridan Aquifer System .....                          | 62         |
| <b>Chapter 4: Model Development.....</b>               | <b>73</b>  |
| <b>    Simulation of Groundwater Flow.....</b>         | <b>73</b>  |
| Conceptual Model.....                                  | 73         |
| Computer Code Selection .....                          | 73         |
| MODFLOW with SFWMD Source Code.....                    | 74         |
| Well Package Modifications and Additions .....         | 75         |
| Strongly Implicit Procedure Package Enhancements ..... | 76         |
| Model Design .....                                     | 76         |
| Hydrologic Data Input.....                             | 79         |
| Boundary Conditions .....                              | 82         |
| Hydraulic Conductivities .....                         | 85         |
| Starting Heads.....                                    | 87         |
| Vertical Conductance (Vcont) .....                     | 91         |
| River Package.....                                     | 97         |
| Drain Package.....                                     | 101        |
| Evapotranspiration (ET) Package .....                  | 103        |
| Recharge.....  | 113        |
| Applied Stresses.....                                  | 127        |
| <b>Chapter 5: Model Calibration.....</b>               | <b>133</b> |
| <b>    Steady-State Model Calibration .....</b>        | <b>133</b> |
| Calibration Criteria and Targets.....                  | 133        |
| Calibration Process.....                               | 133        |
| Calibration Locations .....                            | 134        |
| Calibration Results.....                               | 138        |
| Sensitivity Analysis .....                             | 171        |
| Model Verification .....                               | 174        |
| Model Limitations.....                                 | 192        |
| <b>Chapter 6: Summary and Conclusions .....</b>        | <b>193</b> |
| <b>    Summary and Conclusions .....</b>               | <b>193</b> |
| <b>    References Cited.....</b>                       | <b>195</b> |

## APPENDICES

|   |     |
|---|-----|
| Appendix A: Temperature and ET Stations ..... | A-1 |
| Appendix B: Public Water Supply .....         | B-1 |
| Appendix C: Agricultural Water Supply .....   | C-1 |
| Appendix D: Model Simulations .....           | D-1 |
| Appendix E: Observations Sites .....          | E-1 |



## LIST OF TABLES

|                  |  |     |
|------------------|--|-----|
| <b>Table 1.</b>  | Schematic Cross-Reference to Cited Literature.....   | 17  |
| <b>Table 2.</b>  | Water Classification by Salinity (Source: Kasenow 1997). ....  | 55  |
| <b>Table 3.</b>  | Some Parameters in the Primary and Secondary Drinking Water Regulations, Florida Administrative Code, 1982.....          | 55  |
| <b>Table 4.</b>  | Water Quality of the Wells in the Surficial Aquifer System. ....   | 58  |
| <b>Table 5.</b>  | Comparison of Water Quality Parameters in the Surficial Aquifer System in Glades County .....                            | 60  |
| <b>Table 6.</b>  | Comparison of Water Quality Parameters in the Surficial Aquifer System in Highlands County .....                         | 60  |
| <b>Table 7.</b>  | Comparison of Water Quality Parameters in the Surficial Aquifer System in Okeechobee County.....                         | 61  |
| <b>Table 8.</b>  | Comparison of Water Quality Parameters in the Surficial Aquifer System in Polk County.....                               | 62  |
| <b>Table 9.</b>  | Comparison of Water Quality Parameters in the Floridan Aquifer System in Glades, Highlands and Okeechobee Counties. .... | 66  |
| <b>Table 10.</b> | Water Quality of the Wells in the Floridan Aquifer System.....   | 72  |
| <b>Table 11.</b> | MODFLOW96 Packages Used in the Model. ....   | 75  |
| <b>Table 12.</b> | Model Domain for the Lower Kissimmee Basin Groundwater Model.....  | 76  |
| <b>Table 13.</b> | Model Input. ....  | 79  |
| <b>Table 14.</b> | Rainfall Stations and Average 1995 Daily Rain.....   | 118 |
| <b>Table 15.</b> | Land Use / Land Cover Descriptions.....  | 122 |
| <b>Table 16.</b> | Calibration Results Layer 1.....   | 138 |
| <b>Table 17.</b> | List of Observation Wells near Lake Isis, Saddle Blanket and Lake Olivia. ....   | 146 |
| <b>Table 18.</b> | Calibration Results Layer 2.....   | 152 |
| <b>Table 19.</b> | Calibration Results Layer 3.....   | 158 |
| <b>Table 20.</b> | Simulated Layer by Layer Volumetric Water Budgets for 1995 (in MGD). ....  | 165 |
| <b>Table 21.</b> | Results of Sensitivity Analysis Lower Kissimmee Basin Groundwater Model (Composite for all Layers).....                  | 171 |

|   |     |
|---|-----|
| <b>Table 22.</b> Results of Sensitivity Analysis Lower Kissimmee Basin Groundwater Model (by Layer) ..... | 173 |
| <b>Table 23.</b> Observation Sites 2004 vs. Observation Sites 1995.....                                   | 180 |
| <b>Table 24.</b> Observed vs. Simulated Water Level 2004, Layer 1.....                                    | 184 |
| <b>Table 25.</b> Observed vs. Simulated Water Level 2004, Layer 2.....                                    | 186 |
| <b>Table 26.</b> Observed vs. Simulated Water Level 2004, Layer 3.....                                    | 187 |

## LIST OF FIGURES

|  |    |
|--|----|
| <b>Figure 1.</b> SFWMD Water Supply Planning Regions.....  | 3  |
| <b>Figure 2.</b> Lower Kissimmee Basin Groundwater Model Project Area.....   | 5  |
| <b>Figure 3.</b> Physiographic Divisions in the Lower Kissimmee Groundwater Model Area.....  | 8  |
| <b>Figure 4.</b> Highlands County Elevation Data.....  | 9  |
| <b>Figure 5.</b> Topography.....   | 10 |
| <b>Figure 6.</b> Major District Structures.....  | 12 |
| <b>Figure 7.</b> Rivers and Lakes Simulated in the Lower Kissimmee Groundwater Basin.....  | 13 |
| <b>Figure 8.</b> Relationship of Hydrogeologic Units in South Florida to Geologic Units and Their Lithology (Reese and Richardson 2004)..... | 16 |
| <b>Figure 9.</b> Base Map for Cross Sections.....  | 19 |
| <b>Figure 10.</b> North South Cross Section 1.....   | 20 |
| <b>Figure 11.</b> North South Cross Section 2.....   | 21 |
| <b>Figure 12.</b> West East Cross Section 1.....   | 22 |
| <b>Figure 13.</b> West East Cross Section 2.....   | 23 |
| <b>Figure 14.</b> West East Cross Section 3.....   | 24 |
| <b>Figure 15.</b> Elevation of the Base of the Surficial Aquifer System.....   | 26 |
| <b>Figure 16.</b> Thickness of the Surficial Aquifer System.....   | 27 |
| <b>Figure 17.</b> Elevation of the Top of the Intermediate Confining Unit.....   | 29 |
| <b>Figure 18.</b> Thickness of the Intermediate Confining Unit.....  | 30 |
| <b>Figure 19.</b> Elevation of the Top of the Upper Floridan Aquifer.....  | 32 |
| <b>Figure 20.</b> Thickness of the Upper Floridan Aquifer.....   | 33 |
| <b>Figure 21.</b> Transmissivity in the Upper Floridan Aquifer (ft <sup>2</sup> /day).....   | 34 |
| <b>Figure 22.</b> Elevation of the Top of the Middle Confining Unit 1.....   | 36 |
| <b>Figure 23.</b> Thickness of the Middle Confining Unit 1.....  | 37 |
| <b>Figure 24.</b> Elevation of the Top of the Middle Floridan Aquifer.....   | 39 |

|   |    |
|---|----|
| <b>Figure 25.</b> Thickness of the Middle Floridan Aquifer.....   | 40 |
| <b>Figure 26.</b> Transmissivity in the Middle Floridan Aquifer (ft <sup>2</sup> /day)) .....                 | 41 |
| <b>Figure 27.</b> Elevation of Top of Middle Confining Unit 2 .....   | 43 |
| <b>Figure 28.</b> Thickness of the Middle Confining Unit 2.....   | 44 |
| <b>Figure 29.</b> Elevation of Top of Lower Floridan Aquifer .....  | 46 |
| <b>Figure 30.</b> Watersheds .....  | 48 |
| <b>Figure 31.</b> Drainage Basins.....  | 49 |
| <b>Figure 32.</b> May 1995 Potentiometric Surface of the Upper Floridan Aquifer System.....                   | 51 |
| <b>Figure 33.</b> September 1995 Potentiometric Surface of the Upper Floridan Aquifer System.....             | 52 |
| <b>Figure 34.</b> Estimated Average 1995 Potentiometric Surface of the Upper Floridan Aquifer System.....     | 53 |
| <b>Figure 35.</b> Compare Water Levels in Nested Well Romp 28.....  | 54 |
| <b>Figure 36.</b> Water Quality Well Sites by Aquifer System. ....  | 56 |
| <b>Figure 37.</b> Water Quality Profile of SWFWMD ROMP Well 28.....   | 64 |
| <b>Figure 38.</b> Water Quality Profile of SWFWMD ROMP Well 14.....   | 65 |
| <b>Figure 39.</b> Piper Diagram of the Surficial Aquifer Wells in Glades County. ....                         | 67 |
| <b>Figure 40.</b> Piper Diagram of the Surficial Aquifer Wells in Highlands County.....                       | 68 |
| <b>Figure 41.</b> Piper Diagram of the Surficial Aquifer Wells in Okeechobee County.....                      | 69 |
| <b>Figure 42.</b> Piper Diagram of the Floridan Aquifer Wells in Glades County.....                           | 70 |
| <b>Figure 43.</b> Piper Diagram of the Floridan Aquifer Wells in Okeechobee County. ....                      | 71 |
| <b>Figure 44.</b> Example of Model Grid for Simulating 3-Dimensional Groundwater Flow. ....                   | 74 |
| <b>Figure 45.</b> Model Mesh.....   | 78 |
| <b>Figure 46.</b> Vertical Discretization of Model Layers. ....   | 81 |
| <b>Figure 47.</b> IBOUND Layer 1.....   | 83 |
| <b>Figure 48.</b> IBOUND Layer 2 and 3.....   | 84 |
| <b>Figure 49.</b> Hydraulic Conductivity K (ft/day) Values Used for Layer 1 (Surficial Aquifer System). ..... | 86 |

|  |     |
|--|-----|
| <b>Figure 50.</b> Starting Heads for the Surficial Aquifer Layer.....  | 88  |
| <b>Figure 51.</b> Starting Heads for the Floridan Aquifer Layers.....  | 90  |
| <b>Figure 52.</b> Calibrated Vcont Values for the Intermediate Confining Unit.....   | 92  |
| <b>Figure 53.</b> Calibrated Vertical Hydraulic Conductivity for the Intermediate Confining Unit.....                        | 93  |
| <b>Figure 54.</b> Estimated Vcont Values for the Middle Confining Unit 1.....  | 95  |
| <b>Figure 55.</b> Estimated Vcont Values for the Middle Confining Unit 2.....  | 96  |
| <b>Figure 56.</b> Lakes, Rivers, Streams and Canals.....   | 100 |
| <b>Figure 57.</b> Drains.....  | 102 |
| <b>Figure 58.</b> Evapotranspiration Surface (ft).....   | 104 |
| <b>Figure 59.</b> Extinction Depths.....   | 106 |
| <b>Figure 60.</b> Comparison of Temperatures in Wauchula and Avon Park.....  | 108 |
| <b>Figure 61.</b> Evapotranspiration Station Locations and Thiessen Polygons.....  | 110 |
| <b>Figure 62.</b> Max Potential Evapotranspiration Rate.....   | 112 |
| <b>Figure 63.</b> Recharge in the Model Area.....  | 114 |
| <b>Figure 64.</b> Rainfall Stations and Thiessen Polygons.....   | 116 |
| <b>Figure 65.</b> Average 1995 Rainfall by Station.....  | 117 |
| <b>Figure 66.</b> Generalized Soils in the SFWMD.....  | 120 |
| <b>Figure 67.</b> Land Use 1995.....   | 126 |
| <b>Figure 68.</b> Public Water Supply Wells.....   | 128 |
| <b>Figure 69.</b> Agricultural and Other Irrigated Wells.....  | 130 |
| <b>Figure 70.</b> Observation Sites, Layer 1.....  | 135 |
| <b>Figure 71.</b> Observation Sites, Layer 2.....  | 136 |
| <b>Figure 72.</b> Observation Sites, Layer 3.....  | 137 |
| <b>Figure 73.</b> Observed Versus Simulated Layer 1 (Surficial Aquifer System) Water Levels,<br>Average 1995 Conditions..... | 141 |
| <b>Figure 74.</b> Layer 1 Water Level Residuals for 1995 Calibration.....  | 141 |

|   |     |
|---|-----|
| <b>Figure 75.</b> Layer 1 Water Level Residuals for 1995 Calibration (Map).....   | 142 |
| <b>Figure 76.</b> Simulated Heads Layer 1 (Elevation in ft NGVD).....   | 143 |
| <b>Figure 77.</b> Difference in Simulated vs. Starting Head Water Levels (Map).....   | 144 |
| <b>Figure 78.</b> Inset with Lake Isis, Saddle Blanket and Lake Olivia.....   | 145 |
| <b>Figure 79.</b> Depth to Water (Simulated Layer 1 Water Levels) for Average 1995 Conditions.....  | 147 |
| <b>Figure 80.</b> Contours Simulated Upper Floridan vs. Average 1995 Water Levels in Upper Floridan.....  | 149 |
| <b>Figure 81.</b> Contours Simulated Middle Floridan vs. Average 1995 Water Levels in Upper Floridan.....   | 150 |
| <b>Figure 82.</b> Difference between Water Levels in Layers 2 and 3.....  | 151 |
| <b>Figure 83.</b> Simulated Heads Layer 2 - Elevations.....   | 153 |
| <b>Figure 84.</b> Simulated Heads Layer 3 - Elevations.....   | 154 |
| <b>Figure 85.</b> Simulated vs. Starting Heads Layer 2.....   | 155 |
| <b>Figure 86.</b> Observed Versus Simulated Layer 2 (Upper Floridan Aquifer) Water Levels, Average 1995 Conditions.....                                     | 156 |
| <b>Figure 87.</b> Layer 2 Water Level Residuals for 1995 Calibration.....   | 156 |
| <b>Figure 88.</b> Layer 2 Water Level residuals for 1995 Calibration (Map).....   | 157 |
| <b>Figure 89.</b> Simulated vs. Starting Heads Layer 3.....   | 159 |
| <b>Figure 90.</b> Observed Versus Simulated Layer 3 (Middle Floridan Aquifer) Water Levels, Average 1995 Conditions.....                                    | 160 |
| <b>Figure 91.</b> Layer 3 Water Level Residuals for 1995 Calibration.....   | 160 |
| <b>Figure 92.</b> Layer 3 Water Level Residuals for 1995 Calibration (Map).....   | 161 |
| <b>Figure 93.</b> Critical Water Supply Problem Areas.....  | 163 |
| <b>Figure 94.</b> Areas Where the Floridan Aquifer is under Artesian Conditions.....  | 164 |
| <b>Figure 95.</b> Net Flow - Cumulative Volume (MGD) by Layer.....  | 166 |
| <b>Figure 96.</b> Simulated Vertical Flows between Layer 1 (Surficial Aquifer System) and Layer 2 (Upper Floridan Aquifer) for Average 1995 Conditions..... | 168 |
| <b>Figure 97.</b> Simulated Vertical Flows between Layer 2 (Upper Floridan Aquifer) and Layer 3 (Middle Floridan Aquifer) for Average 1995 Conditions ..... | 169 |

|   |     |
|---|-----|
| <b>Figure 98.</b> Simulated Vertical Flows between Layer 3 (Upper Floridan Aquifer) and Layer 4 (Middle Floridan Aquifer) for Average 1995 Conditions ..... | 170 |
| <b>Figure 99.</b> 2004 Observation Wells.....   | 177 |
| <b>Figure 100.</b> Observed vs. Simulated Water Levels in Observation Sites used for Calibration in 2004.....   | 178 |
| <b>Figure 101.</b> Observed vs. Simulated Water Levels in Observation Sites (2004 Conditions) .....   | 179 |
| <b>Figure 102.</b> Observed vs. Simulated Water Levels in Observation Sites Layer 1 (2004 Conditions).....  | 182 |
| <b>Figure 103.</b> Observed vs. Simulated Water Levels in Observation Sites Layer 2 (2004 Conditions).....  | 183 |
| <b>Figure 104.</b> Observed vs. Simulated Water Levels in Observation Sites Layer 3 (2004 Conditions).....  | 187 |
| <b>Figure 105.</b> Difference in Water Levels 1995 AG and 2004 AG Surficial Aquifer.....  | 189 |
| <b>Figure 106.</b> Difference in Water Levels 1995 AG and 2004 AG Upper Floridan Aquifer.....   | 190 |
| <b>Figure 107.</b> Difference in Water Levels 1995 AG and 2004 AG Middle Floridan Aquifer. ..   | 191 |

